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MEASURING PROCEDURAL IMITATION APTITUDE IN CHILDREN: FURTHER VALIDATION OF THE PRESCHOOL IMITATION AND PRAXIS SCALE (PIPS)[1, 2, 3]

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Summary.—The Preschool Imitation and Praxis Scale (PIPS) was developed to measure bodily and procedural imitation aptitude in young children. However, the investigation of procedural imitation is more complex than that of bodily imitation. The procedural imitation tasks of the PIPS mainly consisted of unusual acts upon objects (for example, switching on a lamp in a toy animal with the forehead). This study assessed the suitability of these tasks by ruling out nonimitative learning in 15 typically developing children between 12 and 55 mo. of age (6 girls, 9 boys). Results indicated that the tasks seem novel and unlikely to be performed spontaneously by the children. In addition, the number of target acts performed by the children in the imitation condition was significantly higher than in the baseline, investigator-manipulation, and imitation-enhancement nonimitative control conditions. Finally, the tasks elicited more frequently imitative behaviour than end-state emulation. Therefore, the tasks appear appropriate to measure procedural imitation, and the findings support the theoretical validity of the PIPS.

Motor imitation (hereafter "imitation") is often thought of as a low-level, cognitively undemanding, even childish form of behaviour. Recent work across a variety of sciences argues that imitation is an extraordinary ability that is fundamentally linked to characteristically human forms of intelligence (Hurley & Chater, 2005). Imitation is the capacity of an individual to replicate an observed behaviour. It involves the ability to transform perceptual information into a motor copy of it (Prinz, 2002). An unambiguous definition of imitation is given by Tomasello and colleagues, who state that it is a novel action learned by observing another person performing it, and, in addition to novelty, it requires a means/ends struc-

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ture. The observer copies the actor's means of achieving his result (Tomasello, Carpenter, Call, Behne, & Moll, 2005).

Rumiati and Tessari (2002) assumed the existence of two distinctive kinds of imitation regarding the representational content of the observed actions and two different neural mechanisms. The first is the imitation of nonmeaningful and/or novel unfamiliar actions for which the goal can only be identified retrospectively. This imitative performance can only take a direct route, bypassing long-term memory and transforming visuospatial characteristics directly into motor representations (Rumiati & Tessari, 2002) as evidenced by activation of areas belonging to the dorsal stream (Rumiati & Bekkering, 2003). The second is the imitation of meaningful and/or familiar, and/or well-trained actions for which the observer can identify a meaning or a goal and possesses a template in long-term memory (Rumiati & Tessari, 2002). In addition to shared neural processes, this kind of imitation involves indirect semantic processing by activation of areas belonging to the ventral stream (Rumiati & Bekkering, 2003). A goal can be a salient feature from a presented action (Gattis, Bekkering, & Wohlschläger, 2002; Mizuguchi, Sugimura, & Deguchi, 2009). Recently, Carmo and Rumiati (2009) found that imitation performance among healthy adults engaged in a speeded imitation task was significantly poorer when meaningful gestures involved objects (e.g., hammering with an imaginary hammer), rather than no objects (e.g., waving good-bye), suggesting that the use of objects increases processing demands (Carmo & Rumiati, 2009).

Imitation plays a central role in the acquisition of daily living skills and in the general adjustment and adaptive behaviour of children. Because imitation is essentially a no trial-and-error learning experience, it leads to safe and rapid learning in young children. Bodily imitation, i.e., gestural and facial imitation, serves primarily as a means of social interaction and the acquisition of social behaviour (Want & Harris, 2002). Procedural imitation, the copying of actions upon objects, serves primarily as a means of social learning of instrumental behaviour and of skilled acts or praxis. It allows children to pick up spontaneously a vast arsenal of daily life skills (Want & Harris, 2002; Masur, 2006).

Problems with imitation are frequently reported in children with autism spectrum disorders (Williams, Whiten, & Singh, 2004; Vanvuchelen, Roeyers, & De Weerdt, 2011b, 2011c) and with intellectual disabilities (Meyer, 1998; Macedoni-Luksic, Greiss-Hess, Rogers, Gosar, Lemons-Chitwood, & Hagerman, 2009; Vanvuchelen, Feys, & De Weerdt, 2011). Since imitation is central for young children to learn how to do things conventionally in their culture, a test to identify young children with such problems is evidently important. There are currently four published measures

frequently used in clinical settings to assess imitation abilities in young children. Although these measures rely on a theoretical framework and have consistency in their scores, they pay very limited attention to procedural imitation (Bergès & Lézine, 1963; Užgiris & Hunt, 1987; Ayres, 1989; Korkman, Kirk, & Kemp, 1998). To address this issue, the authors developed the Preschool Imitation and Praxis Scale (PIPS), which was designed to assess the accuracy of bodily and procedural imitation performances in young children (Vanvuchelen, 2009; Vanvuchelen, Roeyers, & De Weerdt, 2011a, 2011d; Vanvuchelen & Vochten, 2011). The theoretical framework and deductive test construction approach of the Preschool Imitation and Praxis Scale (PIPS) have been described in detail elsewhere (Vanvuchelen, *et al*., 2011a). To recap briefly, different action types, based on research with apraxic adults, were selected to tap a broad range of possible imitation mechanisms: action types with different effects (salient environmental and internal), representational levels (meaningful and nonmeaningful; goal-directed and nongoal-directed), temporal complexities (single and sequential) and visual monitoring possibilities (transparent and opaque). The PIPS consists of ten task categories: six gestural, one facial, and three procedural (Vanvuchelen, *et al*., 2011c). Intrarater and interrater reliability of the PIPS items and the total score have been established. Results of test-retest analysis indicated that the PIPS score is stable over time (Vanvuchelen, *et al*., 2011d). Bodily and procedural imitation age-equivalent scores are derived from PIPS scores of 654 typically developing children between 1 year and 4.9 years of age (Vanvuchelen, 2009).

However, examining aptitude for procedural imitation is more complex than for bodily imitation. The presence of objects can potentially evoke a number of mechanisms of nonimitative social learning (Sevlever & Gillis, 2010). Therefore, two major principles were adhered to during the design of the procedural imitation tasks of the PIPS. First, the tasks consist of actions upon objects with unusual means which children would be unlikely to demonstrate spontaneously, but which are well within the range of their motor abilities (Meltzoff, 1988). With regard to this principle, it is important to document the children's familiarity with the objects and their pre-existing repertoire of actions with the objects. It may be that the objects themselves provoke target acts in children, e.g., trial-and-error learning independently of the interventions of the investigator (Meltzoff, 1988; Want & Harris, 2002).

Second, the tasks differentiate between imitative learning and learning by nonimitative example following (Want & Harris, 2002; Whiten, 2006; Sevlever & Gillis, 2010). With regard to this principle, it is important to distinguish procedural imitation from nonimitative behaviour. Procedural imitation entails a specific causal relationship between observation

of a feature of a model's movement upon an object (*fm*), and execution by the observer of a movement with the same feature (*fo*). The extent of similarity between the executed (*fo*) and demonstrated (*fm*) movement is the most important criterion in evaluating imitation (Heyes, 2001). Dissimilarity distinguishes imitation from other types of actions with objects. In object movement re-enactment, children copy the movement of an object instead of the model's movement (Whiten, 2006). In end-state emulation, children copy the result, but not the means of the model's action. In this case, children use movements from their own existing repertoire (Huang & Charman, 2005; Whiten, 2006). Social learning of object use also appears without copying behaviour. In stimulus enhancement learning, children show an increased interest in the object upon which the model performs an action. During affordance learning, children learn about the characteristics of an object by the model's actions, such as functions of the object or the relationship between objects, without copying the actions of the model (Whiten, 2006).

This study investigates the suitability of the procedural imitation tasks of the PIPS by ruling out possible nonimitative trial-and-error learning, stimulus enhancement and affordance learning, object movement reenactment, and end-state emulation. If the number of target acts performed by the children after observing these actions in the model is substantially higher than in any other condition, the tasks of the PIPS are suitable to assess procedural imitation abilities in children of the target age.

Method

Participants

Fifteen children within the age range of the PIPS participated in this study: six girls and nine boys between 12 and 55 mo. of age ($M = 40.1$ mo., $SD = 13.8$). Criteria for admission into the study were that the children were not preterm born (more than 36 wk. gestation age and birth weight above 1,500 grams) and had no known physical, sensory, or mental handicap according to the parental report in the Ages and Stages Questionnaire (ASQ). The ASQ is a parent-administered structured questionnaire that includes questions on five domains of child development: communication, gross motor, fine motor, problem-solving, and personal-social skills. The scores for each domain are summed, and if the score for any of the five domains is abnormal, the ASQ is considered to be abnormal. Specificity, the ability of the ASQ system to correctly identify typically developing children, is high: 86%. Sensitivity, the ability to detect delayed development, is average: 72% (Bricker & Squires, 1999). The parents of all children signed an informed consent form prior to participation of their children.

Measure: Preschool Imitation and Praxis Scale (PIPS)

In the present study, three categories of procedural imitation tasks of the PIPS were involved: (1) goal-directed, substituted actions upon objects (sao-P), which are illogical actions with respect to the familiar functions of the objects (e.g., switching on a lamp in a toy animal with your forehead); (2) goal-directed actions upon substituted objects (aso-P), in which the functions of the objects are illogical with respect to the familiar actions (e.g., turning a cup upside-down and playing drums on it with two spoons); and (3) nongoal-directed action sequences upon objects (sq-P), which are characterized by simple nongoal-directed actions presented in a specific sequence (e.g., opening a box, removing a wooden block, turning the box upside-down, and putting the block on the bottom of the box). The three task categories with three tasks each are described in Table 1. Results of intra- and interrater reliability of the nine procedural imitation tasks of the PIPS indicated that they can be scored reliably by a trained investigator without video recording. The within- and between-raters weighted kappa values of the sao-P tasks are between .91 and 1.00; of the aso-P tasks between .75 and 1.00, and of the sq-P tasks between .57 and .85 (Vanvuchelen, *et al*., 2011d).

Procedure and Study Design

Two identical sets of objects of the PIPS were used. Each child was individually assessed in a quiet room and was seated at a table in front of the trained investigator. In line with Meltzoff (1988), the children were offered the objects one by one in three control conditions, each lasting one minute, and one test condition to elicit the target acts. Video recordings

TABLE 1

Description of the Three Procedural Task Categories With Three Tasks Each of the Preschool Imitation and Praxis Scale (PIPS)

Category	Task	Task Description
sao-P	sao-P1	Raise a toy bear by pulling a cord.
	sao-P2	Put a wooden block on top of your head.
	sao-P3	Switch on a lamp in a toy animal with your forehead.
aso-P	aso-P1	Turn a cup upside-down and play drums on it with two spoons.
	aso-P2	Remove the cap of a doll and put a shoe on the head of the doll.
	aso-P3	Put a toy car in bed, turn it upside-down, and tuck it in with a blanket.
sq-P	sq-P1	Open the box, put the lid on the table, turn the box upside-down, put the block on the bottom of the box.
	sq-P2	Take the block from the bottom of the box, turn the box to a normal position again, close the box, put the block on the lid of the box.
	sq-P3	Take the block from the lid of the box, open the box, put a disc into the box, close the box, put the block again on the lid of the box.

Note.—sao-P = substituted-actions-upon-objects; aso-P = actions-upon-substituted-objects; sq-P = action-sequences-upon-objects.

were made of the children's performance in the three control conditions to be coded by two trained investigators. The four conditions are represented in a diagram (Fig. 1).

During the baseline control condition, the children were offered an object or a combination of objects with the instruction: "Show me what you can do with this?" It was assumed that if the children performed a target act without any intervention of the investigator, the children reacted purely on the characteristics of the object by trial-and-error learning.

During the investigator-manipulation control condition, the children were offered an object or a combination of objects. The investigator manipulated an identical object or combination of objects and used actions that were unrelated to the actual actions of the children or to the target acts of the PIPS (Appendix 1: a detailed description of the non-target acts for each task in this condition, p. 791). No verbal instruction or information were given. It was assumed that the observation of the actions of the investigator drew the attention of the children to the objects or the possible combined use of two or more objects in one action. It enhanced the possibility that the children discovered the characteristics of the objects and the target acts. This procedure was used to rule out that children would learn the target acts by stimulus enhancement or affordance learning.

During the imitation-enhancement control condition, the children were offered an object or a combination of objects and the investigator imitated the actions of the children. No verbal instruction or information were given. The recognition of being imitated could motivate the children to manipulate the objects in many different ways. This was done to discover various combinations to use the objects (Nadel, 2002) and to repeat

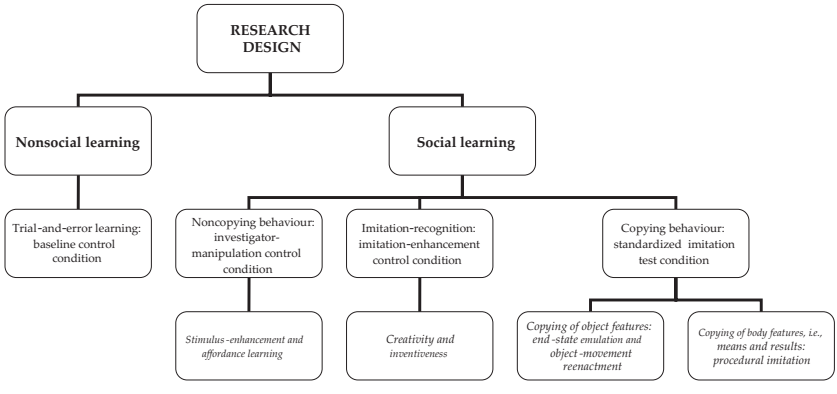

FIG. 1. Diagram of the research design in nonsocial and social learning strategies in actions upon objects

these actions to test the investigator, or "testing" behaviour (Meltzoff & Decety, 2003). This condition allowed the authors to rule out that children performed the target acts from their own creativity and inventiveness.

The test condition consisted of the standardized use of the PIPS and was offered one week later. The investigator placed the object or combinations of objects in front of her, so that they were clearly visible for the children but outside their reach. Before demonstrating each task, a child's attention was attracted by addressing the child by name. During the test, only the verbal instruction "(Name), you do this too" was given. After the demonstration, the object or combination of objects was offered to the children, while the objects used by the investigator remained on the table. It was assumed that if the children copied the result of a target act in a different way, the children learned by end-state emulation (actions-upon-substituted-objects and substituted-actions-upon-objects) or object movement reenactment (action sequences upon objects). In contrast, if the children did not perform the target act spontaneously, but copied the form as well as the result after observation of the target act, the children reacted purposefully on the observation of the modeled action upon the object (procedural imitation).

Scores

In all conditions, the following scores were given: 2 if the target act was achieved, 1 for a partial spatiotemporal resemblance with the target act, and 0 if no resemblance with the target act was achieved (Appendix 2: a detailed description of the scores for each task according to the spatiotemporal resemblance with the target acts, p. 792). For each condition, the sum score on the nine tasks was calculated.

Statistical Analysis

Cohen's kappa was used to assess consensus between two independent observers in the three control conditions. The interpretation of kappa values was done according to Fleiss (1981): below .40 agreement by coincidence; between .40 and .60 moderate, between .61 and .75 good, and above .75 excellent. Inter-observer percentage of agreement of more than 70% was considered acceptable. Simple descriptive statistics (frequency) were used for the analysis of the number of performances with a full resemblance with the target acts (Score 2). Friedman's nonparametric repeated-measures comparison was used to compare the sum scores of the target acts in the four conditions. *Post hoc* analysis of the sum scores in the individual conditions was carried out with a Wilcoxon signed-ranks test. Correlation between chronological age and summary score was examined with the Spearman's rank correlation coefficient. Multiple regression analysis was used to explain the variance of the number of target acts in the

standardized imitation test. All analyses have been performed using the statistical software SPSS Version 16.0. Values smaller than $p = .05$ were considered significant.

Results

Analysis of the Reliability of Observations

Table 2 provides the kappa values and percentages of agreement for the interrater agreement of individual task scores in the three control conditions. The interrater reliability was moderate to excellent and the percentages of agreement were acceptable.

Analysis of the Individual Actions Upon Objects in the Four Conditions

Table 2 provides the number of participants producing acts upon the objects with a score of zero (no spatiotemporal resemblance with the target act), one (partial spatiotemporal resemblance with the target act), or two (full spatiotemporal resemblance with the target act) in the four conditions. Table 3 is a raw data matrix and shows the number of participants producing the target acts (Score 2) under each of the four conditions. Each participant was presented with 9 test stimuli and was thus assigned a score ranging from 0 to 9 according to the number of acts produced with full spatiotemporal resemblance to the target act.

Nonsocial trial-and-error learning processes were observed in the baseline control condition. Three out of 15 children produced spontaneously one act with a full spatiotemporal resemblance with the target act. Two children raised the toy bear by pulling the cord (sao-P1) and one child put the car in bed, turned it upside-down, and tucked it in with a blanket (aso-P3).

Stimulus enhancement and affordance learning were observed in the investigator-manipulation control condition. Two children produced an act with a full spatiotemporal resemblance with the target act. One child raised the toy bear by pulling the cord (sao-P1) and one child removed spontaneously the cap of the doll and put the shoe on its head (aso-P2).

In the imitation-enhancement control condition, the children were encouraged to perform rather unfamiliar acts. One child produced three acts and six children one act with a full spatiotemporal resemblance with the target acts. One child raised the toy bear by pulling the cord (sao-P1). Four more acts were twice observed with full resemblance to the target act: put a wooden block on the top of your head (sao-P2), turn a cup upside-down and play drums on it with two spoons (aso-P1), remove the cap of a doll and put a shoe on its head (aso-P2), and put the toy car in bed and tuck it in (aso-P3).

In contrast to the control conditions, in the standardized imitation test condition (PIPS) the children mainly performed actions identical to

TABLE 2

KAPPA VALUES AND PERCENTAGE OF AGREEMENT FOR INTERRATER AGREEMENT OF INDIVIDUAL TASK SCORES IN THREE NONIMITATIVE CONTROL CONDITIONS AND NUMBER OF PARTICIPANTS PRODUCING ACTS UPON OBJECTS WITH NO (SCORE = 0), PARTIAL (SCORE = 1) OR FULL (SCORE = 2) SPATIOTEMPORAL RESEMBLANCE TO THE TARGET ACTS IN 4 CONDITIONS

Task	Control Condition																	
	Baseline (Max. 15)						Investigator Manipulation (Max. 15)						Imitation Enhancement (Max. 15)					
	k	ASE	AG%	0	1	2	k	ASE	AG%	0	1	2	k	ASE	AG%	0	1	2
sao-P1	.67	.16	80	6	7	2	(a)	(a)	93	14	0	1	1.00	.00	100	13	1	1
sao-P2	(a)	(a)	100	15	0	0	(a)	(a)	100	15	0	0	(a)	(a)	87	12	1	2
sao-P3	.72	.17	87	5	10	0	.65	.22	87	10	5	0	1.00	.00	100	9	6	0
aso-P1	(a)	(a)	87	13	2	0	(a)	(a)	80	12	3	0	.54	.22	80	12	1	2
aso-P2	(a)	(a)	100	15	0	0	(a)	(a)	93	13	1	1	.63	.32	93	13	0	2
aso-P3	(a)	(a)	93	13	1	1	(a)	(a)	100	15	0	0	.54	.22	80	12	1	2
sq-P1	(a)	(a)	100	15	0	0	1.00	.00	100	14	1	0	(a)	(a)	93	14	1	0
sq-P2	1.00	.00	100	13	2	0	1.00	.00	100	14	1	0	(a)	(a)	100	15	0	0
sq-P3	.58	.19	80	8	7	0	.42	.33	87	12	3	0	.81	.17	93	11	4	0
Total Number (Max. 135)				10	29	3				11	14	2				11	*15*	*9*

Task	Test Condition		
	Standardized Imitation (Max. 15)		
	0	1	2
sao-P1	2	3	10
sao-P2	2	1	12
sao-P3	4	1	10
aso-P1	2	4	9
aso-P2	2	0	13
aso-P3	3	2	10
sq-P1	2	10	3
sq-P2	2	9	4
sq-P3	3	7	5
Total Number (Max. 135)	*22*	*37*	*76*

Note.—k = kappa value; ASE = asymptotic standard error; AG% = percentage of agreement; (a): kappa statistics could not be computed, because of the skewed distribution of the data.

the target acts that were shown by the investigator (procedural imitation). One child produced eight, four children seven, five children six, one child four, and three children three acts with a full spatiotemporal resemblance with the target acts. Of all demonstrated substituted actions upon objects (sao-P), 2/3 of the children, and of all actions upon substituted objects (aso-P), one-half of the children received a score of 2. They succeeded in copying the proper means as well as the final results of the demonstrated acts. Only one of three children succeeded in imitating complete action sequences (sq-P).

In contrast to procedural imitation, in end-state emulation, children copied the results of the demonstrated acts, using movement of their own repertoire. For that reason, they received a score of 1. End-state emulation was less frequently observed than procedural imitation. Three children piled up the different parts of the toy bear without using the cord (sao-P1), one child placed a wooden block on her face instead of on the top of her head (sao-P2), one child switched on the lamp in the toy animal with his hands instead of his forehead (sao-P3), four children played drums using the spoons without first turning the cup upside-down (aso-P1), two children placed the toy car in bed and tucked it in without turning the car upside-down (aso-P3). Most children fulfilled the action sequences (sq-P) with partial resemblance to the action sequences of the investigator.

Analysis of the Sum Scores of the Target Acts Upon Objects in the Four Conditions

For the sum scores of the target acts in the different conditions (range 0–18), values are medians with the Interquartile Range between parentheses: baseline 2.0 (2–3); investigator-manipulation 1.0 (0–2), imitation-enhancement 2.0 (0–4), control condition and the standardized imitation condition 15.0 (10–16). The Friedman test indicated a statistically significant difference in the sum scores of the target acts in the 15 participants between the four conditions (Friedman's $\chi^2 = 29.2$, $p < .001$).

TABLE 3
Number of Participants Producing Acts with Full Spatiotemporal Resemblance to the Target Acts as a Function of Condition

	n	No. of Participants Producing Target Acts									
		0	1	2	3	4	5	6	7	8	9
Baseline control	15	12	3								
Investigator-manipulation control	15	13	2								
Imitation-enhancement control	15	8	6		1						
Standardized imitation test	15	2			2	1		5	4	1	

Note.—Each participant was presented with 9 tasks and was assigned a score ranging from 0 to 9 according to the number of acts produced with full spatiotemporal resemblance to the target act.

Post hoc analyses showed that the sum scores of target acts in the standardized imitation test condition differed significantly from these in the baseline ($Z = -3.23$, $p = .001$), the investigator manipulation ($Z = -3.30$, $p = .001$), and the imitation-enhancement control condition ($Z = -3.31$, $p = .001$). In contrast, the differences between the sum scores in the baseline versus investigator-manipulation ($Z = -1.81$, $p = .07$), the baseline versus imitation-enhancement ($Z = -0.24$, $p = .80$), and the investigator-manipulation versus imitation-enhancement condition ($Z = -1.76$, $p = .08$) were not statistically significant.

Association with Age

Summary scores of the target acts in the baseline control condition ($r_s = .17, p = .54$), investigator-manipulation control condition ($r_s = .35, p = .20$), and imitation-enhancement control condition ($r_s = .47$, $p = .07$; 95%CI = −.02, .80) were not significantly correlated to chronological age. In contrast, the summary score of the target acts in the standardized imitation test condition (PIPS) was statistically significantly and positively correlated to chronological age ($r_s = .66$, $p = .007$; 95%CI = .20, .87).

Multiple linear regression analysis, using a stepwise variable entry with the variables age and the sum scores of target acts in the three control conditions, indicated that age was the only factor that significantly predicted the sum score of the target acts in the standardized imitation test condition. The age of the children explained nearly 73% of the variance of the imitated target actions ($R^2 = .73$; $F_{1,13} = 34.68$, $p < .001$). The summary score of the target acts in the standardized imitation test condition (X) can be predicted by the following regression equation: X = (.328* chronological age) − .571.

Discussion

The aim of this study was to investigate the suitability of the tasks with objects of the Preschool Imitation and Praxis Scale (PIPS) to measure procedural imitation aptitude in young children. Procedural imitation is essential in learning skilled acts. Clinicians and teachers who are concerned with the education of young children emphasize the importance of this learning strategy (Meyer, Day, & Lee, 1992; Zetou, Tzetzis, Vernadakis, & Kioumourtzoglou, 2002). An assessment to identify children with imitation problems is indispensable.

Procedural imitation implies that a copied action upon an object is a consequence of observing the form as well as the result of the model's action upon an identical object (Tomasello, *et al*., 2005). This can be judged with respect to four interrelated dimensions: contingent versus independent, novel versus familiar, similar versus dissimilar, and immediate versus delayed (Masur, 2006).

The child's action should be contingent upon or evoked by the investigator's behaviour rather than occurring independently. This first principle was investigated by comparing the number of target acts in the test condition (contingency) versus three nonimitative control conditions (independence). In the three control conditions, children performed only occasionally acts with full spatiotemporal resemblance to the procedural target acts of the PIPS. This finding supports the notion that the tasks of the PIPS are novel according to the definition of Meltzoff (1988). Neither the children's trial-and-error strategy, nor drawing their attention to possible manipulation strategies of the objects during nontarget acts of the investigator, nor eliciting their creativity by imitation-recognition could generate target acts at the same level as when demonstrated by the investigator. Even when partial resemblances were taken in account in the summary scores, these were still significantly lower in the control conditions than in the test condition. In the standardized imitation test condition, children performed a high percentage of the target acts. This large proportion of correct responses in the test condition highlights not only the dominant mechanism of imitation, but also that the objects of the PIPS are appropriate to appraise imitation. It can be concluded that the tasks of the PIPS are suitable to investigate procedural imitation according to at least two criterions for imitative behaviour: contingency and novelty (Masur, 2006).

Substituted-actions-upon-objects (sao-P) and actions-upon-substituted-objects (aso-P) are goal-directed actions. In substituted actions upon objects (sao-P), the actions were illogical with respect to the familiar functions of the objects. Nevertheless, the tasks "to raise the toy bear by pulling a cord" and "to switch on a lamp in a toy animal with the forehead" need special attention. Without any demonstration, a considerable number of children discovered the effect of the actions, but not the intended target acts. They stacked up the different parts of the toy bear without using the cord, which would allow them to achieve this in a single action. They switched on the lamp in the toy animal with their hands instead of their heads. In both cases, children deduced from visual cues the properties of the objects. Still they did not succeed in finding the substituted acts.

In actions-upon-substituted-objects (aso-P), the functions of the objects were illogical with respect to the familiar actions. Nevertheless, in the imitation-enhancement control condition, some children found it funny to demonstrate unusual odd scenarios such as putting the toy car in bed instead of the doll. This finding was consistent with the study of Nadel (2002). Children from the age of 18 mo. demonstrate playful unusual behaviour to communicate with the imitator (Nadel, 2002).

The action-sequences-upon-objects (sq-P) were characterised by simple nongoal-directed actions presented in a specific sequence (e.g., open-

ing a box, removing a wooden block, turning the box upside-down, and putting the block on the bottom of the box). None of the children could deduce the goal and sequence of the actions from visual cues of the objects. Consequently, action-sequences-upon-objects met the novelty criterion for imitation. Therefore, it was not surprising that none of the children in any of the three control conditions performed these target acts. This finding was consistent with the study of Elsner and colleagues in 9- to 15-mo.-old children performing a three-step action sequence with toys (Elsner, Hauf, & Aschersleben, 2007).

In the investigator-manipulation control condition, the investigator demonstrated nontarget acts. The underlying idea was to attract the children's attention to the properties of the objects, such as the cord of the toy bear, and to encourage them to discover the target acts by stimulus enhancement and affordance learning. The children were more likely to imitate the modeled nontarget acts. This was in line with the findings of Meltzoff (1995).

The main characteristic of imitation is the close relationship between the action of the investigator and the response of the child under examination. Consequently, imitation performances should be evaluated on the criterion of similarity versus dissimilarity (Masur, 2006). Therefore, the spatiotemporal resemblance between the copied acts and the modeled target acts served as gold standard for evaluating the probability of the tasks to measure imitation rather than end-state emulation (Heyes, 2001). This principle was investigated in the imitation-test condition. In this condition, all substituted actions upon objects (sao-P) and actions upon substituted objects (aso-P) were more often copied with full than with partial spatiotemporal resemblance with the modeled acts. Therefore, we can assume that these acts were copied as a consequence of the observation of the model's movements, i.e., the means, as well as the effect of these movements, i.e., the result. This finding is in line with Meltzoff's experiment with 14-mo.-old children. In the imitation condition of Meltzoff's study, the majority of children used their foreheads instead of their hands to switch on a lamp as demonstrated by the investigator (Meltzoff, 1988). In an interesting variant on Meltzoff's study, Gergely, Bekkering, and Kiraly (2002) asked the model to switch on a lamp with the forehead in two test conditions. When the 14-mo.-olds observed the model, who had both hands free, they copied the movement of switching on the lamp with the forehead. In contrast, when the model's hands were occupied, they frequently switched on the lamp with their hands. They seemed to assume that the model would have used the hands if she would have been able to do so. The finding of Gergely and colleagues suggests that children evaluate the rationality of the means in relation to the constraints of the situ-

ation (Gergely, *et al.*, 2002). In a hands-free condition, only one of the 15 children used the hands instead of the forehead in the relevant imitation test condition.

The finding that children modeled their copying behaviour preferably on both the observation of the means and the result of a modeled act was consistent with the studies of others (e.g., Bellagamba & Tomasello, 1999; Elsner, 2007; Lyons, Young, & Keil, 2007) and indicates the dominant nature of procedural imitation over end-state emulation. In Lyons, *et al.*'s (2007) study, children reproduced all parts of the model's actions upon objects, even when the causal significance of these actions appeared to be odd. In reproducing the exact and detailed features of the model's actions, children are likely to disentangle the goal of an observed action when it is not completely clear to the child, or to learn about initially opaque aspects of causality (Lyons, *et al.*, 2007).

In the imitation test condition of the present study, some children did not produce all steps of the action-sequences-upon-objects (sq-P), and so they did not succeed in the reproduction of the end position of the objects. It has to be mentioned, that the three sequential tasks were the most difficult procedural imitation tasks of the PIPS (Vanvuchelen, 2009). Moreover, copying nongoal-directed actions could only be based on directly matching the spatiotemporal features of the demonstrated acts. In contrast, to copy goal-directed actions upon objects, children may have used an additional indirect semantic-related imitation strategy. For instance, when the examiner demonstrated, "Put a toy car in bed, turn it upside-down, and tuck it in with a blanket," children may have identified the goal, possessed a template in their long-term memory, and may have thought, "The examiner is doing this odd behaviour as if the toy car is a doll" (Vanvuchelen, *et al.*, 2011a).

Theoretically, one could argue that exposure to the objects during one min. in each control condition could improve the imitation abilities of the children. In the present study, previous experience with the objects, expressed in the summary scores of the target acts in the three control conditions, did not substantially influence the imitation score. This finding was in line with the results of the studies of Barr and Hayne (1996) and Kressley and Knopf (2006). In contrast to the effect of exposure to the objects, age of the children explained nearly 73% of the variance of the imitated target actions in the current study. This finding indicated that the tasks were suitable to study imitation development.

Some limitations of this study can be mentioned. The age range of the sample (12–55 mo.) was large to cover the age range of the PIPS. But the sample size ($N = 15$) was small because of the time-consuming qualitative analysis of the children's responses. The three control conditions were

not counter-balanced. However, it is possible that the previous experience with the objects in counter-balanced control conditions would have had a larger effect on the imitation abilities of the children than in the present study design. Latency scores were not measured, that is, the time elapsed between the presentations of the objects and the production of the target acts. It might be that the occasionally discovered target acts upon objects in the control conditions took more time than in the imitation test condition. It is also possible that in the imitation test condition, children reproduced actions upon objects after a greater latency time as a result of emulation learning (Huang, Heyes, & Charman, 2002). Further, the relative contributions of imitation versus emulation and affordance learning were not investigated by means of a "ghost condition," in which an effective mechanical operation of the objects is seen to occur without human interference (Thompson & Russell, 2004; Huang & Charman, 2005). This kind of study design would demand imitation from prerecorded video demonstrations, which would be very dissimilar to the live demonstrations of the PIPS. Furthermore, in the imitation-enhancement control condition it was assumed that the children were able to recognize when they were being imitated, but imitation recognition was not coded.

Some implications of this study for clinical use of the PIPS can be made. To measure imitation with this developmental imitation test, it is important to present the objects in a standardized way. For instance: before the demonstration, the investigator must present the objects in front of him/herself so that the objects are clearly visible for the child but outside his reach. This approach may prevent the child from discovering functions of the objects without any previous demonstration. The test conditions are described in detail in a manual and guide to item instruction of the PIPS (Vanvuchelen, 2009).

Overall, the finding that the target acts upon the objects of the PIPS seemed novel for children and otherwise not probable to be executed without modeling, as well as the finding that the performance of children in the standardized imitation test elicited more frequently imitative behaviour than end-state emulation, support the notion that the tasks of the PIPS are suitable to measure procedural imitation in preschool children.

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APPENDIX 1

A Detailed Description of the Nontarget Acts For Each Task in the Investigator-manipulation Control Condition

Task	Nontarget Investigator Manipulation
sao-P1	Lifting up the toy bear by the cord in upside-down position
sao-P2	Placing the block on the back and the palm of the hand
sao-P3	Moving the toy animal from one side of the tabletop to the other
aso-P1	Swinging around the cup using two spoons
aso-P2	Seating the doll in the shoe and moving it from one side of the tabletop to the other
aso-P3	Riding the car over the bed
sq-P1	Piling up the box, lid, and block in several positions
sq-P2	Piling up the box, lid, and block in several positions
sq-P3	Piling up the box, lid, block, and disc in several positions

APPENDIX 2

Detailed Description of the Scores For Each Task According to the Spatiotemporal Resemblance With the Target Acts

Score	Task
Target act: to raise a toy bear by pulling the ring of a cord (sao-P1)	
2: Perfect	The child pulls the ring to raise the toy bear.
1: Partial	The child constructs the toy bear by piling up the wooden cubes using his/her hands.
0: No	The child manipulates the toy bear without trying to raise it.
Target act: to put a wooden block on the top of the head (sao-P2)	
2: Perfect	The child puts the block on the top of his/her head.
1: Partial	The child puts the block on another part of the head instead of the top, e.g., the nose.
0: No	The child manipulates the block without touching the head with the block.
Target act: to switch on a lamp in a toy animal with the forehead (sao-P3)	
2: Perfect	The child touches the toy animal with his/her head.
1: Partial	The child switches on the lamp in the toy animal with his/her hand(s).
0: No	The child manipulates the toy animal without trying to switch on the lamp.
Target act: to turn a cup upside-down and play drums on it with two spoons (aso-P1)	
2: Perfect	The child turns the cup and plays drums on it with the two spoons.
1: Partial	The child plays drums on the cup without turning it upside-down or turns the cup upside-down without playing the drums.
0: No	The child manipulates the cup and spoons in a conventional way (e.g., stirring).
Target act: to remove the cap of a doll and put a shoe on the head of the doll (aso-P2)	
2: Perfect	The child removes the cap of the doll and puts a shoe on the head of the doll.
1: Partial	The child removes the cap of the doll without putting the shoe on the doll's head or puts the shoe on the doll's head without removing the cap.
0: No	The child manipulates the doll and shoe in a conventional way (e.g., putting the shoe on the foot of the doll).
Target act: to put a toy car in bed, turn it upside-down and tuck it in with a blanket (aso-P3)	
2: Perfect	The child turns the toy-car upside-down, puts it in bed, and tucks it in with the blanket.
1: Partial	The child puts the car and the doll in bed, or puts the car in bed without turning it upside-down or without tucking it in.
0: No	The child manipulates the doll, car, and bed in a conventional way (e.g., riding the car, putting the doll in bed).
Target act: to open the box, put the lid on the table, turn the box upside-down, put the block on the bottom of the box (sq-P1)	
2: Perfect	The child opens the box, puts the lid on the table, turns the box upside-down, and puts the block on the bottom of the box.
1: Partial	The child executes the sequence incompletely.
0: No	The child manipulates the objects without any resemblance to the target sequence.
Target act: to take the block from the bottom of the box, turn the box in normal position again, close the box, put the block on the lid of the box (sq-P2)	
2: Perfect	The child takes the block from the bottom of the box, turns the box in normal position again, closes the box, and puts the block on the lid of the box.
1: Partial	The child executes the sequence incompletely.
0: No	The child manipulates the objects without any resemblance to the target sequence.
Target act: to take the block from the lid of the box, open the box, put a disc into the box, close the box, put the block again on the lid of the box (sq-P3)	
2: Perfect	The child takes the block from the lid of the box, opens the box, puts a disc into the box, closes the box, and puts the block again on the lid of the box.
1: Partial	The child executes the sequence incompletely.
0: No	The child manipulates the objects without any resemblance to the target sequence.